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THE EXERCISE OF CONTROL OF FLOWING WELLS AND OF INPUT TO GAS LIFT INSTALLATIONS BY MEANS OF A DIFFERENTIAL FLOW CONTROL VALVE*

By L. R. DE VERTEUIL † (Associate Member)

THE use of chokes, or beans, of either the fixed or manually adjustable types for controlling the flow from wells and the input to gas lift installations, has been standard practice in oilfields ever since the need for restriction or control of flow was recognized. This simple method of flow restriction, coupled with the very general practice of fitting wells with 2-inch flow strings, whether the production rate is 5 or 500 b.d., constitute difficulties for the production engineer and in connexion with the all-important gas : oil ratios of flowing wells.

In the case of artificial lift wells, where the control of input gas rates is exercised by means of fixed or manually adjustable chokes, efforts to reduce input gas : oil ratios are often frustrated by defects inherent in such a method of control.

The cause of inefficient production may therefore be due to one or the other of the above causes, or a combination of both.

The purpose of this paper is to show that the intelligent use of a differential flow controller, such as described in Appendix I, will help to reduce, or eliminate, the idiosyncracies arising from the use of fixed, or manually adjustable, chokes at the surface of oil well installations.

Flowing Wells

The use of a fixed choke at any point in the tubing flow-string of a well provides a simple means of restricting flow. It does, in fact, serve as a means of volumetric flow control, provided that the fluid remains reasonably homogeneous throughout. It has been observed [1, 3] that, if the ratio of the GOR at the tubinghead (in cu. ft/brl) to the tubinghead pressure (in p.s.i.a.), or R_T/P_T, has a value between 0·45 and 1·85, the flow mixture of gas and oil is for all practical purposes regular, so that effective volumetric rate control can be usually exercised by means of a fixed choke in the flow stream. For a flow criterion, $R_T/P_T < 0{\cdot}45$, an example showing nature of flow is given in Chart I.

If, however, R_T/P_T be greater than 1·85, the flow ceases to take the form of an unstable foam and becomes a " heading " flow, characterized by the delivery of alternate gas and oil slugs, or pistons. This " heading " phase persists in varying degree over a very wide range of conditions. Example, showing transition from heading to steady flow at a flow criterion of

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† Apex (Trinidad) Oilfields Ltd.

$R_T/P_T < 1{\cdot}85$ is given in Chart II. Well was flowing through a surface choke, $\frac{4}{32}$ inch dia.

A second example is also given of a similar transition as shown on Charts IIA, IIA (2), and IIA (3). Well was producing through an $\frac{8}{32}$-inch dia choke.

Throughout the wide range of flow by heads the fixed choke cannot exercise a constant volumetric control, because during each cycle the flow stream passing through the choke is alternately changing from gas to liquid. For critical flow conditions, which usually pertain, the ratio of the gas : oil velocity, through a fixed choke, is given approximately by equating :—

$$86{\cdot}5\sqrt{S/(G[P_T - P_S])} \quad \text{. . . Equation (1), Appendix II.}$$

where P_T = tubinghead pressure, p.s.i.a.
P_S = separator pressure, p.s.i.a.

If, for example, the mean tubinghead pressure be 65 p.s.i.a. and the separator pressure be 15 p.s.i.a., the flow condition for gas heads is critical, and the mean gas : oil velocity ratio is :

$$86{\cdot}5\sqrt{0{\cdot}9/(0{\cdot}64 \times 50)} = 14{\cdot}6.$$

Thus, the gas slug can escape through the surface fixed choke at a velocity approximately 14·6 times that of the oil. Abundant evidence is available to demonstrate that, under heading conditions, the fixed choke fails to provide effective volumetric flow control, and furthermore, that it contributes very largely to the violent degree of heading by effecting alternate rapid acceleration and deceleration of the flow column. If, also, the effect of deceleration during delivery of an oil head is sufficient to limit the gas flow rate at the entrance to the flow string to that of the slippage velocity, flow may thereby be arrested.

Heading is a phenomenon of some complexity, depending to a large extent upon, *inter alia*, flow rates, gas : oil ratio, depth and diameter of tubing, well-head pressure, expansion ratio, and control. Tapering of flow strings and improvement in flow control provide the readiest means of limiting heading and its effects by minimizing variations in tubinghead pressure and in the dynamic weight of the flow columns.

Exercise of efficient surface control alone cannot thus eliminate that heading inherent in a system, but it can eliminate that degree of heading arising mainly from the use of fixed chokes, and it can assist greatly in minimizing heading, the degree of which is amplified by the use of fixed chokes.

If a downstream-type flow controller is substituted for a surface choke, the relationship between gas and oil velocities in the tubing can be expressed approximately :—

$$109{\cdot}5\sqrt{SP_M/GP_T^2} \quad \text{. . . Equation (2), Appendix II.}$$

when S = sp. gr. of the oil,
G = sp. gr. of the gas,
P_M = downstream or separator pressure, p.s.i.a.,
P_T = tubinghead pressure, p.s.i.a.

Advantage can be taken of this expressed relationship by maintaining a uniform metering pressure to maintain uniform gas and oil velocities, and to reduce substantially the difference between gas and oil velocity in the tubing.

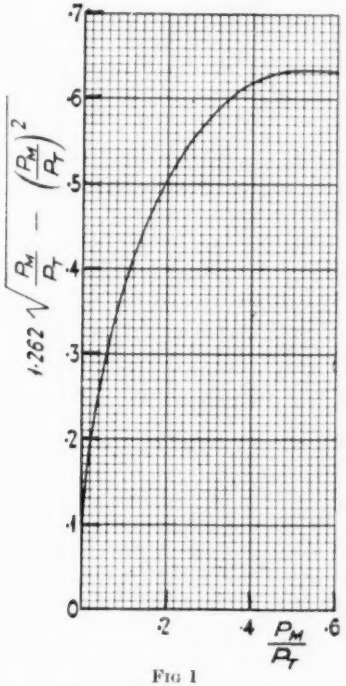

FIG 1

PERFORMANCE CURVE OF CONTROLLER ON THE BASIS OF THE CHOKE UNDER SIMILAR CIRCUMSTANCES

$$\begin{aligned}\text{Controller} &= \frac{109{\cdot}5\sqrt{SP_M/GP_T^2}}{\text{Choke} \quad = 86{\cdot}5\sqrt{S/G(P_T - P_M)}} = 1{\cdot}262\sqrt{(P_M/P_T) - (P_M/P_T)^2}\\ &\text{for values of } P_M/P_T < 0{\cdot}6.\end{aligned}$$

Thus, for the example employed above, the velocity ratio is :—

$$109{\cdot}5\sqrt{0{\cdot}9 \times 15/0{\cdot}64 \times 4225} = 109{\cdot}5 \times 0{\cdot}0707 = 7{\cdot}7/1.$$

This velocity ratio of 7·7 : 1 compares with that of 14·6 : 1 for a fixed choke in the same circumstances.

Referring to Fig 1, it will be seen that the ratio for the example taken falls at a point on the curve where the gas : oil velocity ratio for the controller is approximately 0·5 of that of the choke, when P_M/P_T is equal to 0·23.

It will therefore be seen that, when using a flow controller, an enhancement of the benefits to be obtained thereby is secured when P_M/P_T is of the

order of 0·1 or less. It is clearly an improvement to substitute a differential flow controller for a fixed choke in severely heading wells at low tubinghead pressures, in spite of the unsuitability of the flow string to the conditions.

At Apex (Trinidad) Oilfields Ltd. important improvements in economy and in energy conservation attended the employment of controllers in place of fixed chokes at wells as detailed below :

(*a*) After natural flow had ceased and could not be re-established on chokes, natural flow was sustained for some months.

(*b*) Heading flow, occasioned and sustained by use of chokes, was converted to uniform flow.

(*c*) In the case of intermittent flow at low frequency with dormant intervals due to low gas : oil ratio, the duration of flowing periods was greatly extended and production increased appreciably.

In all cases, a reduction in operating gas : oil ratio was secured. This reduction is considered to be twofold, depending upon reservoir conditions. Due to the method of control, if higher rate of production is attained, this increment may be accompanied by a disproportionate increase in gas. Secondly, and more important, is the fact that the reduction in the amplitude of bottom-hole pressure variation decreases the tendency for "fingering" of mobile extraneous gas into the sphere of influence of the well.

The results of tests carried out on wells of three types are shown in the précis in Appendix III.

Control of Gas Input to Gas Lift Wells

One of the main causes of excessive gas energy consumption of gas lift wells is the somewhat rough control afforded by the almost universal use of fixed, or manually adjustable, chokes for regulating input rates. The input rate must therefore be set sufficienty high to compensate for variations in pressure in the supply system and/or variations in well input pressure.

Four provisions are essential to secure and maintain the highest degree of efficiency of individual wells, both on straight gas lift and plunger lift :—

(1) The control must be unaffected by pressure variations within the gas supply system.

(2) The input gas rate must be controllable at the *minimum* requirement for operation of the well under the prescribed conditions, which in turn demands that provision (3) be complied with.

(3) If, for any reason, such as temporary drop or stoppage of supply, the input pressure to the well increases, the controlled supply rate on resumption must automatically increase, so as to ensure re-establishment of equilibrium, otherwise the well would "load up" and cease production, unless manual readjustment is effected in time to prevent this happening.

(4) If the operation in the well is characterized by heading, slugging, or other intermittent form of flow, gas injection rate should—for efficient operation—vary in *sympathy* with the input pressure on the downstream side of the control.

Choke Control on Input to Well

The rate of gas flow through a manually adjustable or orifice-type choke at any one setting depends upon the upstream and downstream pressures, being a function of the upstream pressure itself and of a factor depending upon the ratio of the downstream to the upstream pressure.

Combining the factors, the rate is proportional[2] to

$$\sqrt{P^2 + 0{\cdot}2222\ PP_1 - 1{\cdot}2222\ P_1^2}$$

where P = upstream pressure, p.s.i.a.
P_1 = downstream pressure, p.s.i.a.

A reduction in input rate is usually accompanied by an increase of the downstream pressure, depending upon the productivity index of the well, etc. Random examples will serve to indicate the degree of control afforded in practice by a choke for critical conditions :

Supply pressure		Well pressure		Ratio of $\frac{\text{Max rate}}{\text{Min rate}}$
Max p.s.i.a.	Min p.s.i.a.	Max p.s.i.a.	Min p.s.i.a.	
265	215	80	75	1·27
415	365	215	210	1·21

The degree of control exercised by the choke in respect of provisions (1) and (2) is thus obviously very insensitive in practice, even for conditions most suited to such a form of control, *i.e.*, when the pressure drop across the choke is excessively high. Other simple examples, but for " non-critical " conditions, will serve to stress this point :—

Supply pressure		Well pressure		Ratio of $\frac{\text{Max rate}}{\text{Min rate}}$
Max p.s.i.a.	Min p.s.i.a.	Max p.s.i.a.	Min p.s.i.a.	
265	215	165	160	1·52
415	365	300	295	1·40

The above evaluations serve to show that the nearer the well-operating pressure approaches to the minimum mean supply pressure, the greater the latitude required in control of input rate to sustain operation. The failure of the choke to qualify in respect of provisions (1) and (2) is thus clearly demonstrated.

In respect of provisions (3) and (4), the control exercised by the choke at any one setting is, of course, exactly contrary to the demands, as can be demonstrated simply by application of the same formula given above.

In consequence, it is impossible by this means to sustain input rates even remotely approaching the minimum rate demanded by the prescribed conditions, in order that continuous maintenance of operation can be

assured. Input rates must, of necessity, range from 25 per cent to several hundred per cent in excess of the requirements, which would apply if the four above-mentioned provisions were complied with.

Downstream Type Differential Controller

An appreciation of requirements in control to fulfil all four provisions clearly indicates that the form of control demanded is essentially that provided by a differential controller of the necessary sensitivity, operating relative to the downstream, or well input, pressure. The flow rate is thus proportional to $\sqrt{HP_1}$, where H = differential, which is a constant at any one setting, and where P_1 = the downstream, or well input pressure.

On this basis all four provisions are satisfied.

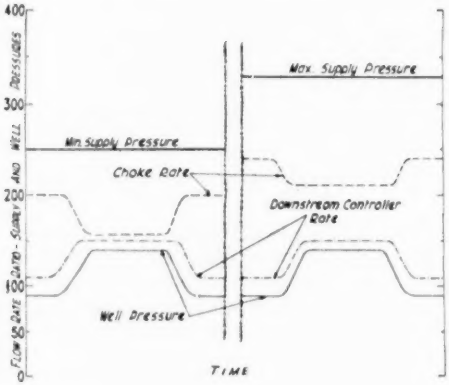

FIG 2

FLOW AND PRESSURE DIAGRAM FOR SLUGGING WELL

Fig 2 shows the comparison of the flow rate through a choke and through a flow controller on the input to a cycling gas lift well, when supply pressure varies.

Sample Charts V demonstrate the sympathetic variation in input flow rate exercised by flow controller when the well input pressure varies.

Charts V (1) demonstrate that the flow control exercised by choke in the same circumstances is antipathetic to the variations in well input pressure, and therefore directly contrary to the requirements of efficient input control.

Charts VA (1) and VA (2) demonstrate that for a uniform well input pressure the input rate as governed by choke varies in sympathy with the supply pressure, whereas when the input is controlled by a flow controller the input rate is independent of variations in supply pressure.

The pressure of the supply system was 200 to 250 p.s.i. It should be appreciated, therefore, that in almost all cases the conditions were par-

ticularly suited to minimizing the contrast between control by chokes and control by flow controllers. In spite of this, the advantage secured by the use of controllers is made abundantly clear by the results of the tests, which show a reduction of over 50 per cent in high pressure gas supply.

Furthermore, the use of controllers would permit of still more efficient operation, where input pressures approximating to minimum supply

Control of Input to Gas Lift Wells : Summary of Tests

No. of test	Tubing		Production method	Manually-adjustable or fixed orifice-type choke			Differential controller downstream type		
	Size, inches	Depth, ft		Casing-head pressure, p.s.i.	Input, cu. ft/ day	Production, b.d.	Casing-head pressure, p.s.i.	Input, cu. ft/ day	Production, b.d.
1	1½ + 1¼	1609	St. lift	170	179,000	19 + 4	135	92,000	35 + 5
2	2½	2529	H.p. lift	30	90,000	33	20	48,000	40
3	2	703	St. lift	115	155,000	78	110	70,000	80
4	2½	956	H.p. lift	9	78,000	9	6	37,000	7 + 1
5	2½	2070	,,	25	115,000	10	19	25,000	15
6	2	742	St. lift	55	172,000	35 + 6	55	90,000	35 + 6
7	2	1366	,,	35–95	130,000	16	35–85	61,000	18
8	2	2647	,,	95–110	135,000	8	80	87,000	8
9	2	2273	,,	115	380,000	10	80	78,000	19
10	2	1184	,,	130	102,000	167	125	96,000	187
					1,536,000	385 + 10		684,000	444 + 12

Note: 19 + 4 = 19 b.d. oil, 4 b.d. free water.

pressure are permissible, whereas operation under such conditions with choke control would be relatively still more wasteful and/or subject to frequent interruptions and failures.

Acknowledgments

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References

[1] May, C. J. *Trans. Amer. Inst. min. (metall.) Engrs*, 1935, **114**, 99.
[2] Gilmour, H. *J. Inst. Petrol.*, 1949, **35**, 574.
[3] Unpublished manuscripts of H. Gilmour on this and allied subjects.

APPENDIX I

Description of Controller

The "ATOL" differential flow controller, is made up of four main parts: the body; the adjustable choke or valve and seat; the metering device; and the adjusting key.

There are two types of "ATOL" flow controllers: the "upstream type" and the "downstream type." (See Figs 3 and 4.)

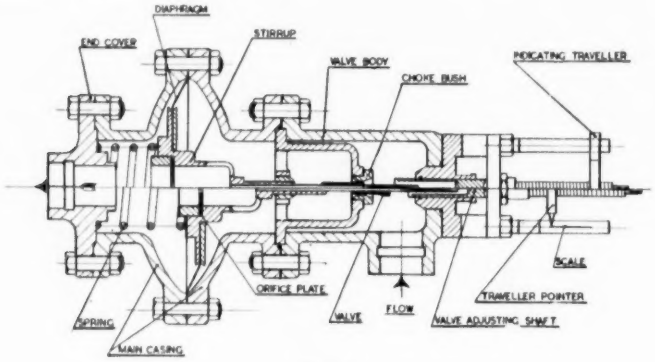


Fig 3

ATOL DOWNSTREAM FLOW CONTROLLER

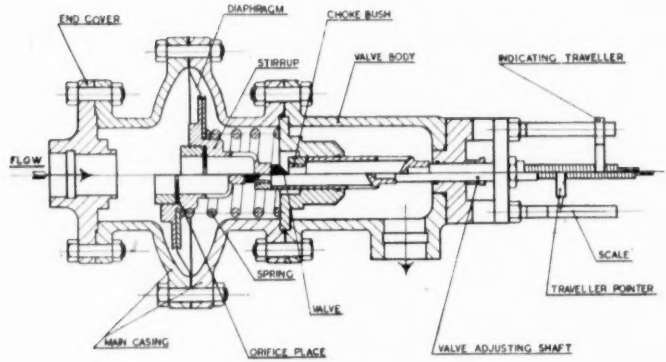


Fig 4

ATOL UPSTREAM FLOW CONTROLLER

The body is constructed of cast steel and is made in two pressure ranges, 600 p.s.i. w.p. and 1500 p.s.i. w.p., with 2-inch inlet and outlet pipe connexions.

The metering device consists of an orifice holder, suspended by a flexible diaphragm held at its periphery between two flanges of the valve body and opposed on the downstream side by a spring.

The adjustable choke, or valve and seat, are of the conical type, with hard facing to resist abrasion.

Adjustment is afforded by a key fitted over the valve stem and extending through a gland to the outside of the body, thus enabling the valve to be moved axially in relation to the seat in the case of the downstream controller while in operation.

In the upstream controller, the seat is fixed in a hollow ported spindle, which extends through a gland to the outside of the body, thus enabling the seat to be moved axially in relation to the valve.

In the case of the "upstream type," the fluid passes first through the metering device and then through the automatically adjustable choke, thus making its control virtually independent of downstream pressure variations, when passing compressible fluids. On entering the body, the fluid passes first through the orifice in the metering device. This puts up a differential pressure across the diaphragm, thus causing compression of the opposing spring and forcing the valve, which, in turn, is integrally connected to the metering device by a stirrup and spindle, towards the valve seat to a point of equilibrium, and automatically maintaining it, thereby securing a constant differential.

The position of the valve seat can be adjusted externally to give a pre-determined differential across the metering device, either before the unit is put into operation, or while it is in operation.

In the case of the "downstream type," the fluid passes first through the variable choke and then through the metering device, thus making its control virtually independent of upstream pressure variations when passing compressible fluids. Otherwise the operation is the same as for the "upstream type," except that adjustment to the differential setting is afforded by moving the valve relative to the seat.

APPENDIX II

Velocity Ratios for Gas and Liquids Through a Fixed Orifice, or Manually-adjustable Choke

$$\textit{Velocity of Gas} = 1050/\sqrt{G} \text{ f.p.s., } P_S < 0{\cdot}57P_T$$

where G = sp. gr. of the gas (air = 1).

Velocity of liquid (neglecting differences in *vena contracta*, etc.)

$$= \sqrt{2gh} \text{ f.p.s.}$$

where g = gravitational acceleration = 32·2 f.p.s.^{2}
$h = P_T - P_S/0{\cdot}434S$, ft = head of liquid across choke.
P_T = upstream pressure, p.s.i.a.
P_S = downstream pressure, p.s.i.a.
S = sp. gr. of liquid (water = 1).

$$\therefore \text{ Gas : oil velocity ratio} = (1050/\sqrt{G})/(\sqrt{64{\cdot}4[P_T - P_S]/0{\cdot}434S})$$
$$= 1050/12{\cdot}18(\sqrt{S/G(P_T - P_S)}$$
$$= 86{\cdot}5(\sqrt{S/G(P_T - P_S)} = \text{Equation (1).}$$

Velocity control for gas and liquids, when flow is controlled by a downstream-type differential flow controller, is exercised by virtue of a fixed differential at separator pressure.

Neglecting changes in temperature and differences in *vena contracta* cross-section, the relationship between gas velocity and oil velocity through the metering orifice is given by :—

$$\sqrt{2gh} \text{ (gas)}/\sqrt{2gh} \text{ (oil) at } P_M$$
$$= \sqrt{62{\cdot}3 \times 14{\cdot}7S/0{\cdot}0763GP_M}$$
$$= \sqrt{1200S/GP_M}$$
$$\therefore \text{ Gas : oil velocity ratio} = 109{\cdot}5\sqrt{S/GP_M}$$

where G = sp. gr. of the gas.
S = sp. gr. of the oil.
P_M = metering or separator pressure absolute.

The above relationship between gas and oil velocities in the *vena contracta* of the measurement orifice provides a basis for determination of the relationship between the gas and oil velocities at the tubinghead.

$$\text{Gas : oil velocity ratio} = 109{\cdot}5\sqrt{S/GP_M} \times P_M/P_T \text{ at tubinghead pressure.}$$
$$= 109{\cdot}5\sqrt{SP_M/GP_T^2} = \text{Equation (2).}$$

APPENDIX III

PRÉCIS OF RESULTS OF TESTS, EMPLOYING A DOWNSTREAM-TYPE DIFFERENTIAL FLOW CONTROLLER IN PLACE OF FIXED-SIZE CHOKES AT TUBINGHEADS OF FLOWING WELLS

The purpose of this précis is to record briefly the consequences resulting from replacing fixed chokes on the tubingheads of wells, which flow by heads, with an automatically variable choke in the form of a differential-type flow controller.

Test No. 1

Natural flow through a fixed choke had ceased prior to the conversion.

Graphical representation of the change in flow characteristics offers the simplest means of demonstrating the immediate results obtained in certain circumstances,

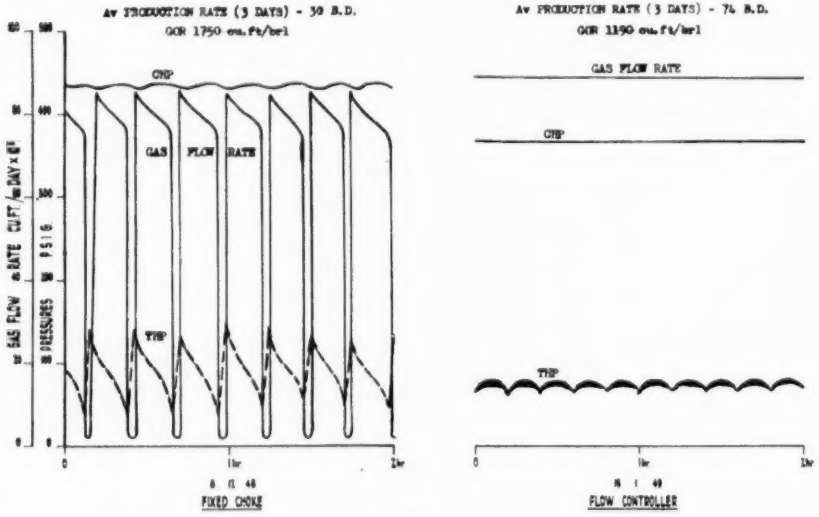


FIG 5

TEST NO 1. THP AND CHP BEFORE AND AFTER INSTALLATION OF FLOW CONTROLLER

when a flow controller is employed in place of a fixed choke. The results, so obtained are presented in graphical form in Fig 5. The following data for this particular well are relevant to an appreciation of the results recorded :—

Diameter of flow tubing	= 2 inches
Depth of flow tubing	= 3060 ft
Diameter of surface choke	= $\frac{5}{32}$ inch
Diameter of casing	= 6 inches

By reference to the diagram it may be readily ascertained that "heading" was for all practical purposes eliminated by the conversion to flow-control and that in consequence the efficiency of lift was very substantially improved, as indicated by :—

(*a*) the reduction in casinghead pressure;
(*b*) the reduction in GOR.

As a result of such improvements the flowing life of a well in such circumstances may be prolonged very appreciably, while still under control throughout. In this

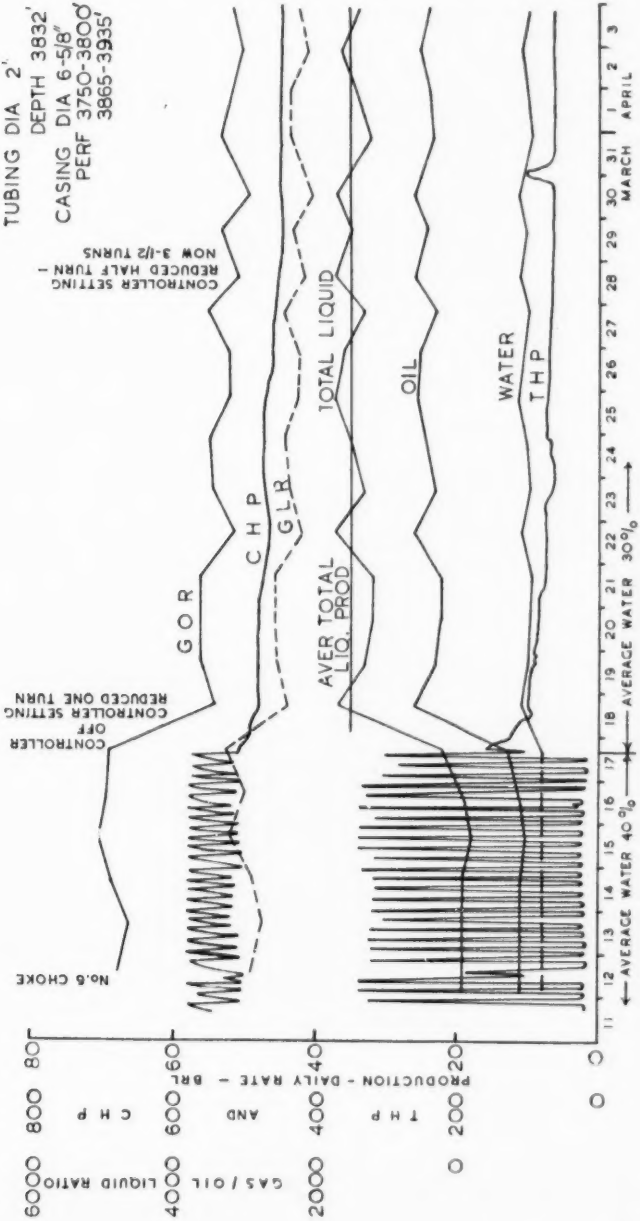


FIG 6
FLOW CONTROLLER TEST NO. 2

case cumulative flowing production was extended by 21 per cent after flow had ceased on a fixed choke.

Test No. 2

The deductions arrived at in Test No. 1 were confirmed in Test No. 2, for which the results of the exercise of the two basic types of well control for appreciable time periods are presented statistically in tabular form below. In this case the heading was due entirely to the use of a fixed surface choke.

Well Data

Diameter of flow tubing = 2 inches
Depth of flow tubing = 3832 ft
Diameter of surface choke = $\frac{6}{32}$ inch
Diameter of casing = 6 inches

Data	Nature of control	
	Tubinghead open $\frac{6}{32}$-inch fixed choke	Controller
Duration of test, days	7	14
Casinghead pressure, p.s.i.g.	580–505	450
Tubinghead pressure, p.s.i.g.	340– 15	63
Rate of oil production, b.d.	11	24
Rate of water production, b.d.	8	10
Rate of liquid production, b.d.	19	34
Gas : oil ratio, cu. ft/brl	4900	3400
Gas : liquid ratio, cu. ft/brl	3200–2800 (average 3000)	2200
Nature of flow	4 heads daily	Uniform

It will be readily noted that, as in the previous case, the nature of flow, characterized by " heading " in the case of a fixed surface choke, was entirely changed to uniform flow, when the flow controller was put in service. See Fig 6 and Charts III and III (2).

The results support the conclusions drawn in Test No. 1, that flow efficiency is substantially increased by elimination of " heading " and that flowing life relative to cumulative production is in consequence increased thereby. At a later stage in the flowing life of the well, the rate of production was 11 brl of oil and $2\frac{1}{2}$ brl of water, employing a flow-controller. The gas : liquid ratio was 1890 cu. ft/brl and the gas : oil ratio was 2300 cu. ft/brl, so that the improvement in GOR following conversion to flow control was not only maintained, but enhanced.

Test No. 3

A third test is included to demonstrate the effects of conversion from fixed to automatic control at the surface in the case, when it is beyond the influence of the controller to eliminate the " heading," arising from subsurface conditions. The well was selected because the heading flow in this case, in addition to its very low frequency, was also characterized by prolonged intervals of no-flow during each cycle, as a direct consequence of the relatively very low producing gas : oil ratio (680 cu. ft/brl on controller).

The results of the test are tabulated below :—

Well Data

Diameter of flow tubing = 2 and $1\frac{1}{2}$ inches
Depth of flow tubing = $1\frac{1}{2}$ inch—3021–3464 ft
Diameter of casing = 9 inches
Depth of casing = 3240 ft
Diameter of liner = $4\frac{3}{4}$ inches
Depth of liner = 3118–4770 ft
Separator pressure = 20 p.s.i.g.

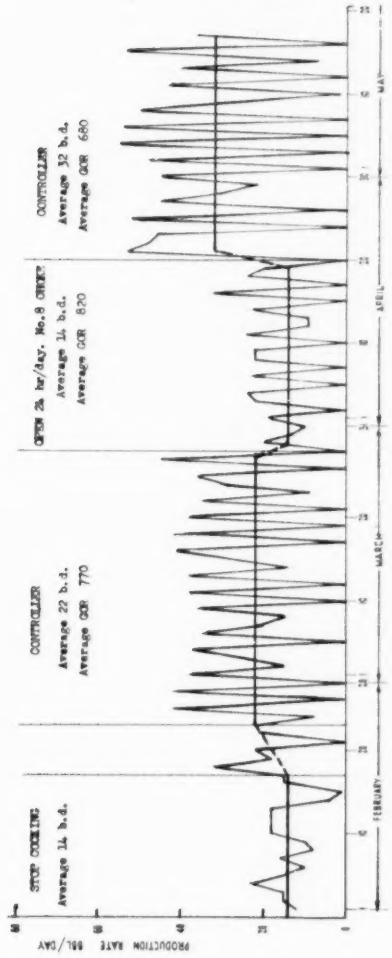
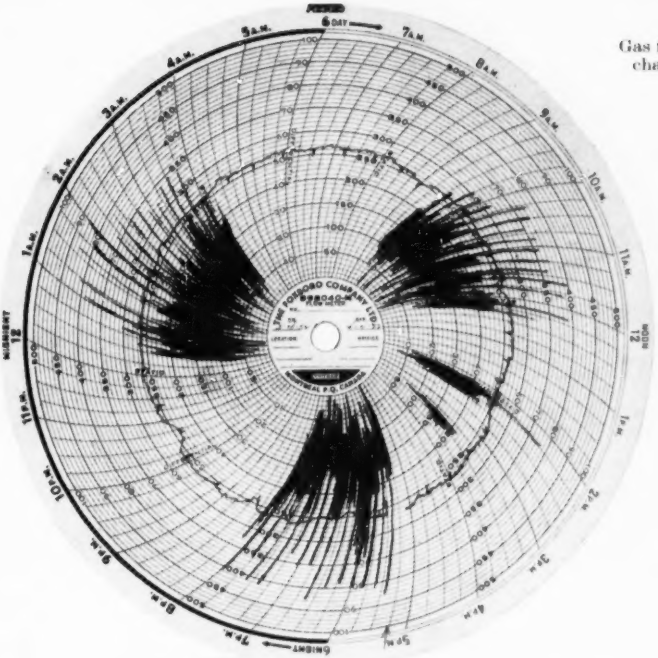


FIG 7
FLOW CONTROLLER TEST NO. 3

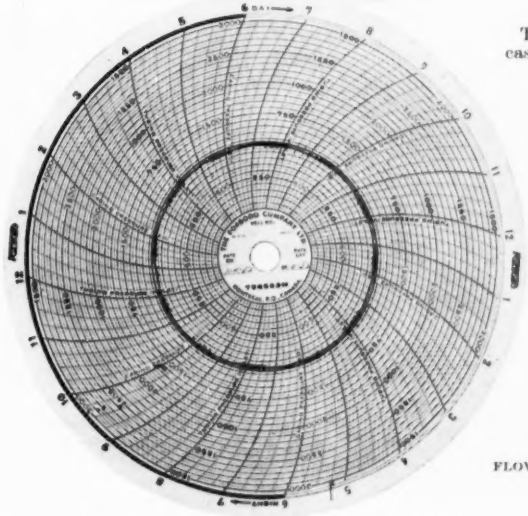
Data	Nature of control			
	Fixed choke		Controller	
	Stopcocking $\frac{6}{32}$ inch choke	Tubinghead open, $\frac{8}{32}$ inch choke	1st Test	2nd Test
Duration of test, days . .	16	23	33	20
Casinghead pressure, p.s.i.g. .	—	685–545	680–505	680–495
Tubinghead pressure, p.s.i.g. .	—	480– 20	445– 20	440– 20
Rate of oil production, brl/day .	13·6	13·9	22·1	31·6
Nature of flow . . .	Heading	Heading	Heading	Heading
Average periodicity, hours/cycle	—	40·3	42·1	41·9
Average duration of flowhead, hr	—	3·3	6·1	7·9

It is recorded above that the frequency of the "heading" was practically unaffected by the conversion. There was a marked prolongation of the flowing period in each cycle, however, and in consequence the production rate and flow efficiency were improved substantially. See Fig 7 and Charts IV and IV (2).

It is evident that the flowing life relative to cumulative production may be prolonged substantially in consequence.



Gas flow chart

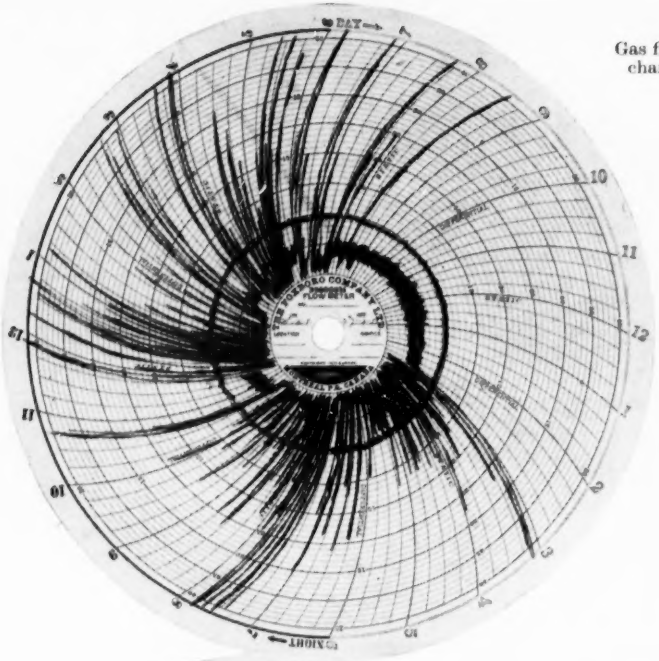


Tubinghead and casinghead pressure chart

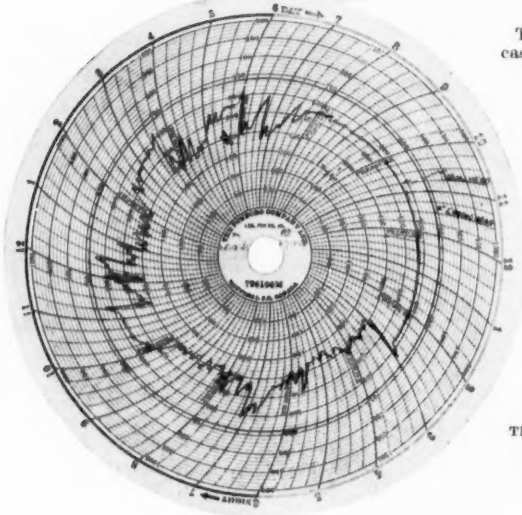
CHART I

FLOW CRITERION LESS THAN 0·45

Production rate . . .	131 b.d.
GOR	290 cu. ft/brl
Tubinghead pressure .	565 p.s.i.a.
API°	22
Criterion	(290–110)/565 = 180/565 = 0·32



Gas flow chart



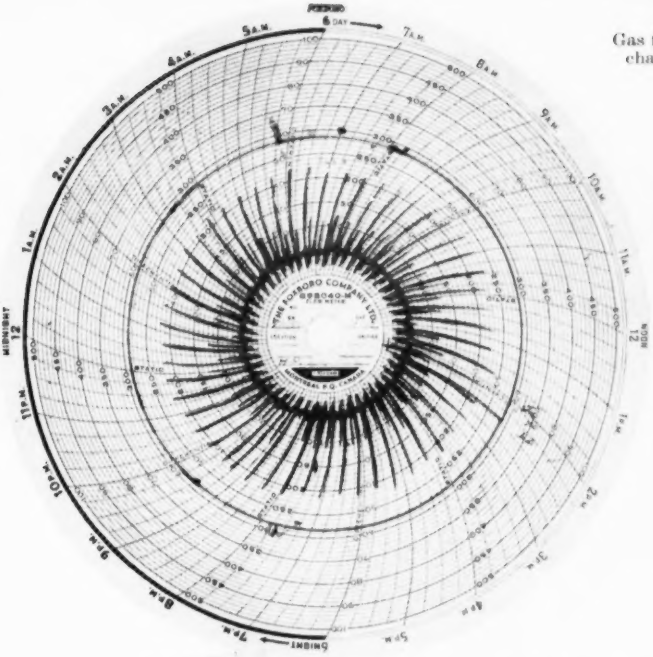
Tubinghead and casinghead pressure chart

CHART II

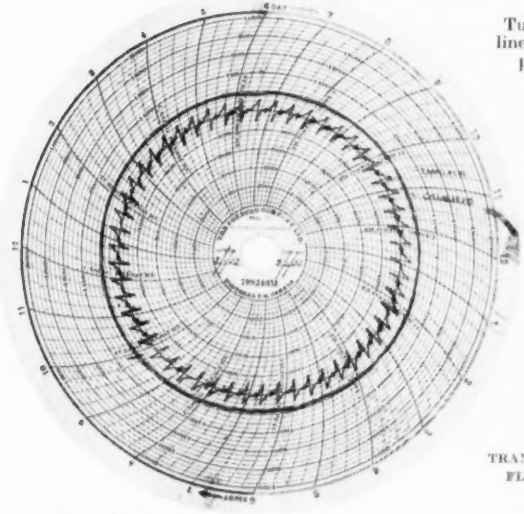
TRANSITION FROM HEADING FLOW TO STEADY FLOW (SLIGHTLY WATERED WELL)

Transient foam flow data :

Production rate	61 b.d.
GOR	585 cu. ft/brl.
Tubinghead pressure	285 p.s.i.a.
API°	22
Criterion	(585–60) 285 = 525/285 = 1·85



Gas flow chart



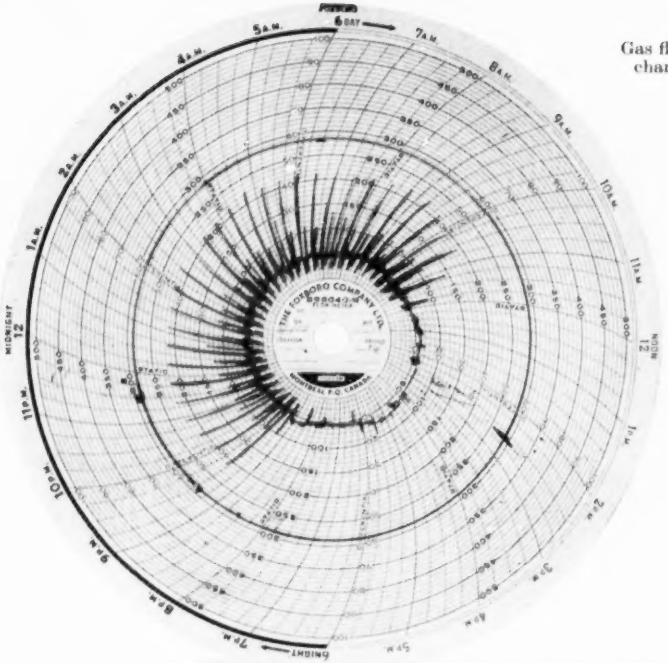
Tubinghead (inner line) and casinghead pressure chart

CHART IIA

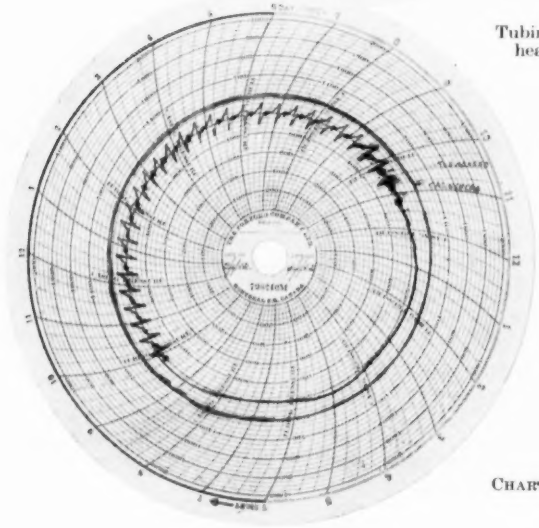
TRANSITION FROM HEADING FLOW TO STEADY FLOW

Foam flow data :

Production rate	267 b.d.
GOR	1140 cu. ft/brl
Tubinghead pressure	285 p.s.i.a.
Criterion	(1140–140)/535 = 1000/535 = 1·87

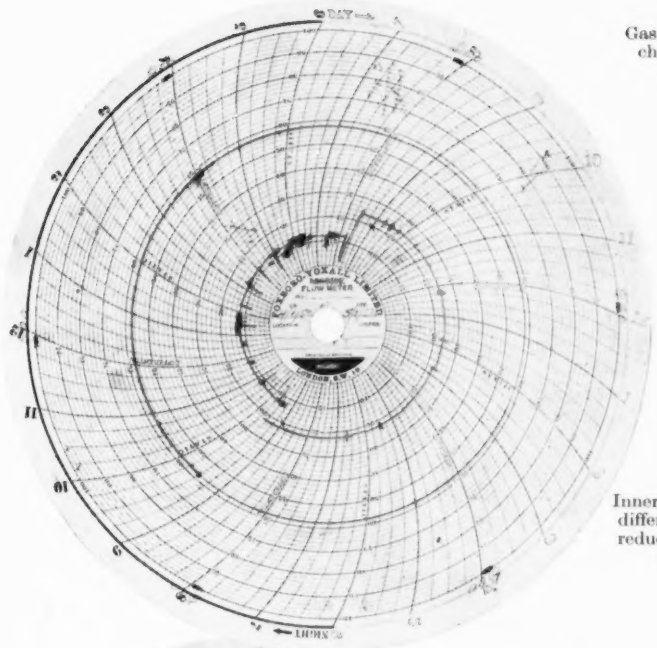


Gas flow chart



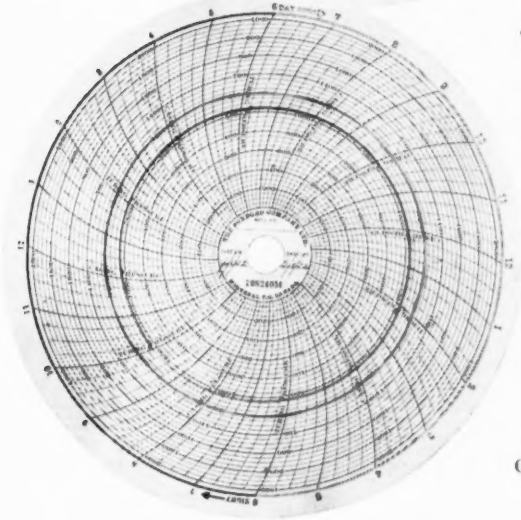
Tubinghead and casing-head pressure chart

CHART IIA (2)



Gas flow chart

Inner line shows differential for reduced orifice plate

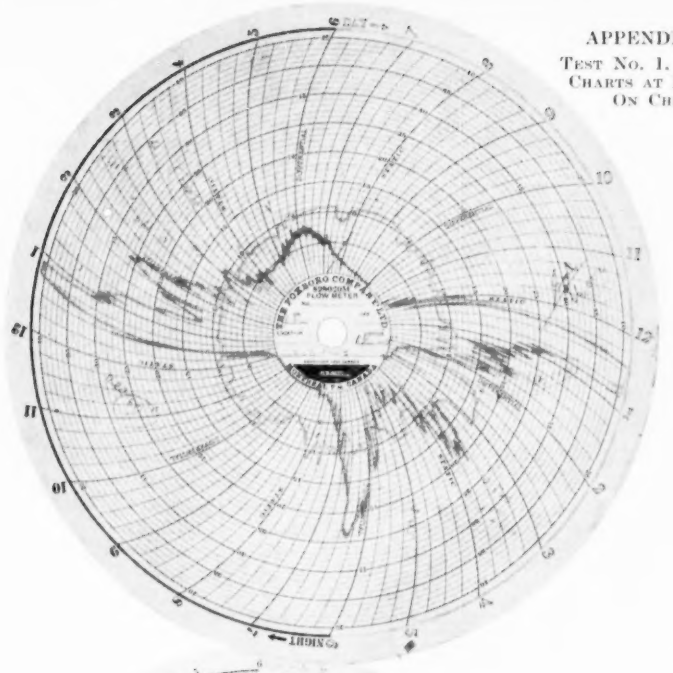


Tubinghead and casing-head pressure chart

CHART IIA (3)

APPENDIX III

TEST NO. 1. SAMPLE CHARTS AT RANDOM, ON CHOKE



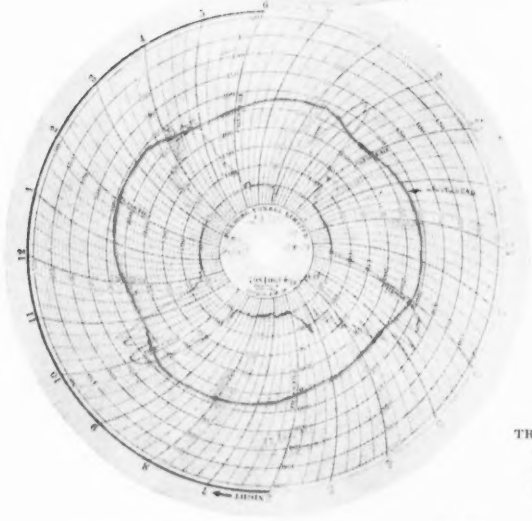


CHART III

TRANSITION FROM HEADING FLOW AND CHOKE CONTROL TO UNIFORM FLOW AND FLOW CONTROLLER

	Choke	Controller
Casinghead, p.s.i.g.	580–505	450
Tubinghead, p.s.i.g.	340– 15	63
Oil production, b.d.	11	24
Water production, b.d.	8	10
Total liquid, b.d.	19	34
GOR	4900	3400
Gas : liquid ratio	3000	2200
Nature of flow	4 heads daily	Uniform

APPENDIX III

Test No. 1. Sample Charts at Random on Controller

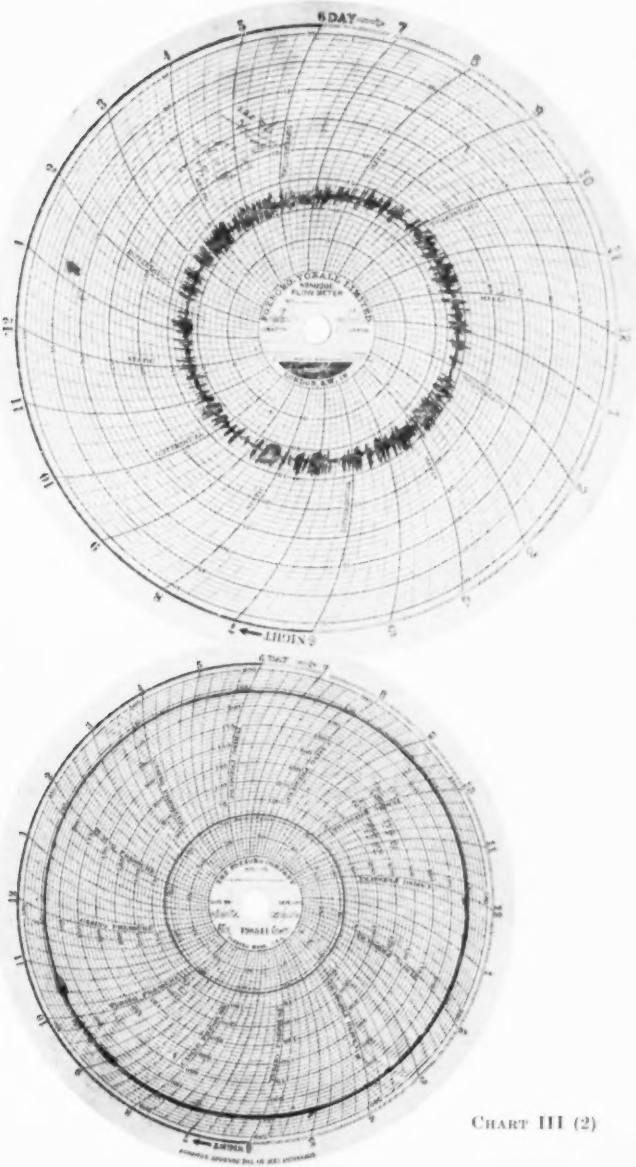
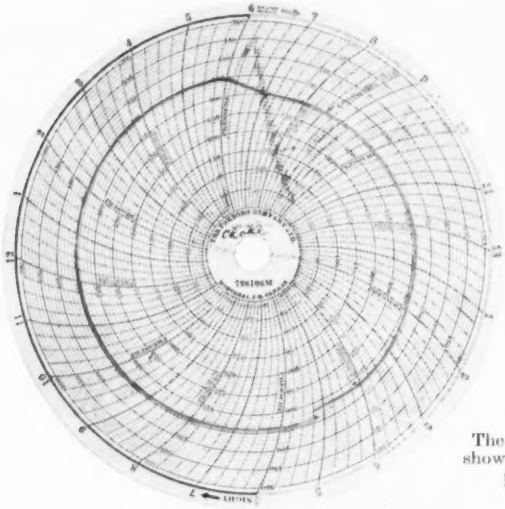


Chart III (2)

APPENDIX III

TEST NO. 2. TUBINGHEAD AND CASINGHEAD PRESSURE CHART. ON CHOKE



The steady line shows casinghead pressure

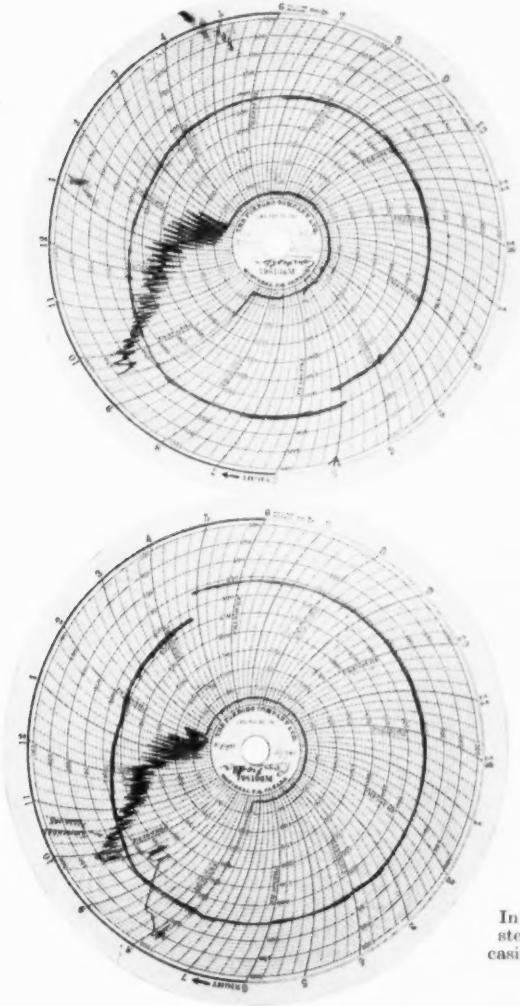
CHART IV

INTERMITTENT FLOWING WELL WITH DORMANT PERIODS—CHART SHOWING EXTENSION OF FLOWING PERIOD ON EACH CYCLE (DURATION OF CYCLE UNCHANGED)

	Choke	Controller
Casinghead, p.s.i.g.	685–595	680–495
Tubinghead, p.s.i.g.	480– 20	440– 20
Oil production, b.d.	14	32
Periodicity, hr/cycle	40·3	41·9
Duration of flow heads, hr . . .	3·3	7·0

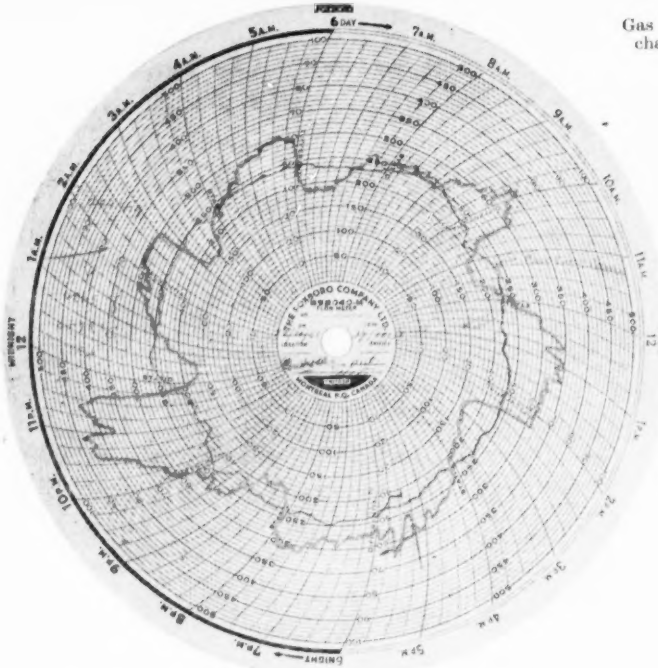
APPENDIX III

Test No. 2. Tubinghead and Casinghead Pressure Charts on Controller



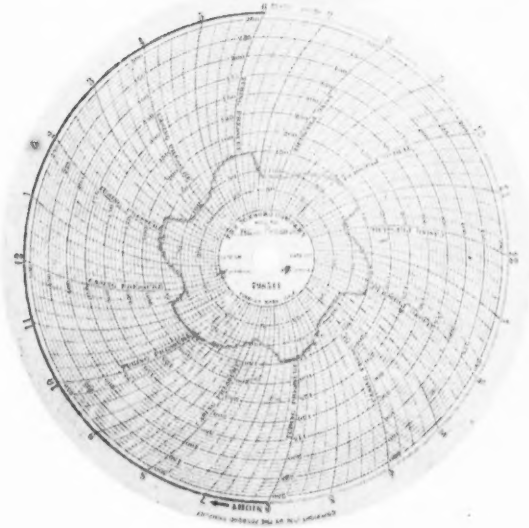
In each chart the steady line shows casinghead pressure

Chart IV (2)



Gas flow chart

The light grey line is for differential



Casinghead pressure chart

CHART V

FLOW CONTROL TO GAS LIFTS

Condition—variable supply pressure, variable well pressure
Input gas control by flow controller

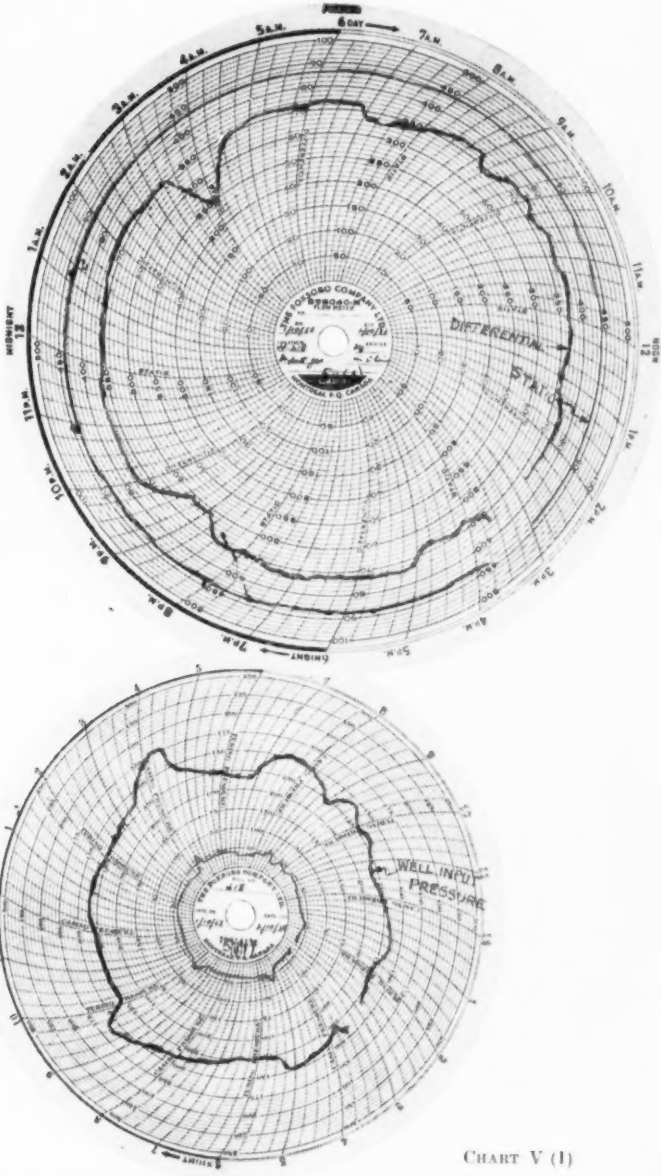
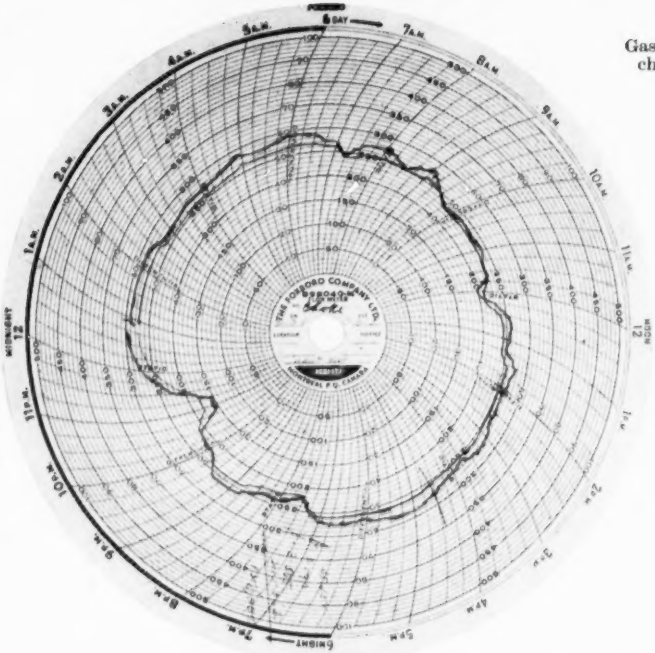
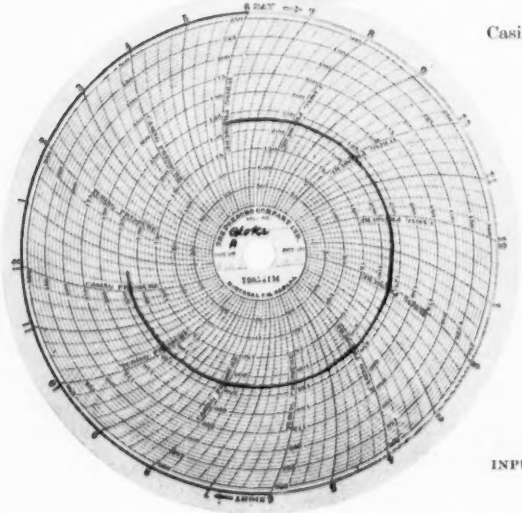


CHART V (1)



Gas flow chart



Casinghead pressure chart

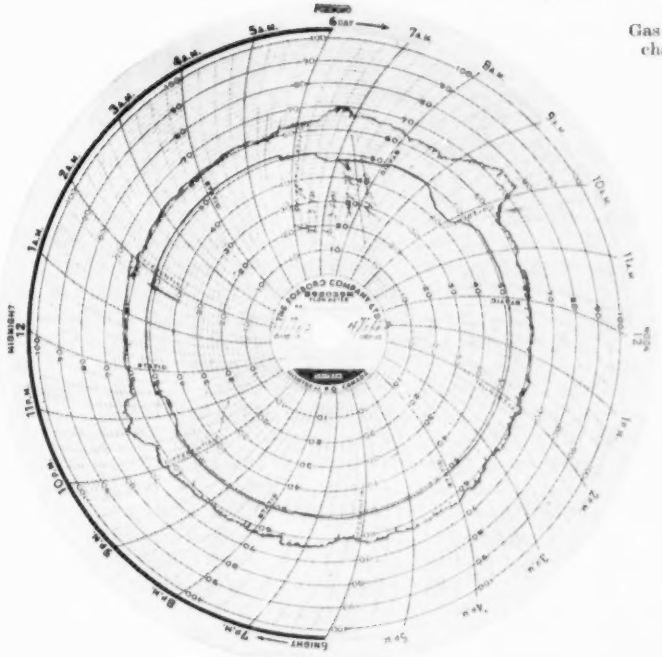
CHART Va (1)

INPUT GAS—FLOW CONTROL TO GAS LIFTS

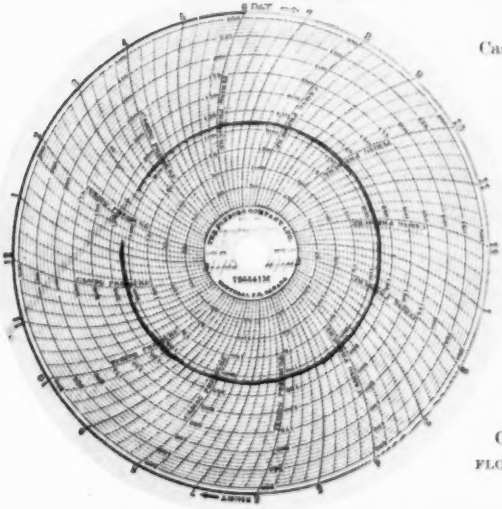
Condition :

Variable supply pressure, uniform well pressure

(1) Choke control (2) Flow controller



Gas flow chart



Casinghead pressure chart

CHART Va (2)
FLOW CONTROLLER

CONVERSION OF KINEMATIC VISCOSITY (CENTISTOKES) TO REDWOOD No. I SECONDS

THE conversion table given in Appendix B to "Standard Methods for Testing Petroleum and its Products," for converting kinematic viscosity (centistokes) to Redwood No. I seconds has been amended by the Viscosity Panel of IP Sub-committee No. 6 on Lubricants, consequent upon the adoption on 1 July 1953 of 1·0038 cs at 20° C (68° F) as the standard value for the kinematic viscosity of water.[1] Prior to that date, the agreed value was 1·0068 cs, so that a reduction of approximately 0·3 per cent is necessary on kinematic viscosity measurements determined by the former method, IP 71/52T. The new value for the kinematic viscosity of water has been adopted in IP 71/53T. Since the values for Redwood seconds obtained by IP 70 may be in error by 1 per cent, the Viscosity Panel has questioned the significance of amending the old table by an amount considerably less than the experimental error. For sake of convenience to those who use the conversion table, however, the Panel has prepared the new table by multiplying the equivalent Redwood No. I seconds given to the first decimal place in the original table (page 566, 8th Edition, "Standard Methods for Testing Petroleum and Its Products," 1947) by 1·0032 and rounding off to the nearest integer.

The Panel has also considered the provision of a simple temperature factor so that the equivalent Redwood seconds at a temperature other than 70° F, 140° F, or 200° F may be obtained. Unfortunately the equation reproducing the figures for 70° F and 200° F with reasonable accuracy is a quadratic, namely

$$R_t = R_{140}\{1 + 1{\cdot}95 \times 10^{-4}(t - 140) + 1{\cdot}12 \times 10^{-6}(t - 140)^2\}$$

where R_t is Redwood seconds at temperature t and R_{140} that at 140° F, so that no simple calculation is available.

---

[1] J. F. Swindells, J. R. Coe, Jr., and T. B. Godfrey. "Absolute Viscosity of Water at 20° C," *Bur. Stand. J. Res. Wash.*, 1952, **48**, 1–31.

Kinematic viscosity, cs	Equivalent Redwood No. I viscosity, sec			Kinematic viscosity, cs	Equivalent Redwood No. I viscosity, sec		
	70° F	140° F	200° F		70° F	140° F	200° F
4	35	36	36	50	204	205	209
4·5	37	37	38	51	208	209	213
5·0	38	39	39	52	212	213	217
5·5	39	40	40	53	216	218	222
6·0	41	41	42	54	220	222	226
6·5	42	43	43	55	224	226	230
7	43	44	44	56	228	230	234
7·5	45	45	46	57	232	234	238
8·0	46	46	47	58	236	238	242
8·5	48	48	48	59	240	242	247
9·0	49	49	50	60	244	246	251
9·5	50	51	51	61	248	250	255
10	52	52	53	62	252	254	259
11	55	55	56	63	256	258	263
12	58	58	59	64	260	262	268
13	61	62	62	65	264	266	272
14	65	65	65	66	269	271	276
15	68	68	69	67	273	275	280
16	71	72	72	68	277	279	284
17	75	75	76	69	281	283	288
18	78	79	80	70	285	287	293
19	82	82	83	71	289	291	297
20	85	86	87	72	293	295	301
21	89	90	91	73	297	299	305
22	93	94	95	74	301	303	309
23	96	97	99	75	305	307	313
24	100	101	103	76	309	311	318
25	104	105	106	77	313	315	322
26	108	109	110	78	317	319	326
27	112	113	114	79	321	324	330
28	116	117	118	80	325	328	334
29	120	121	122	81	329	332	339
30	123	125	126	82	333	336	343
31	127	129	131	83	337	340	347
32	131	133	135	84	341	344	351
33	135	137	139	85	345	348	355
34	139	141	143	86	349	352	359
35	143	145	147	87	353	356	364
36	147	149	151	88	357	360	368
37	151	153	155	89	362	365	372
38	155	157	159	90	366	369	376
39	159	161	163	91	370	373	380
40	164	165	167	92	374	377	385
41	168	169	171	93	378	381	389
42	172	173	176	94	382	385	393
43	176	177	180	95	386	389	397
44	180	181	184	96	390	393	401
45	184	185	188	97	394	397	406
46	188	189	192	98	398	401	410
47	192	193	196	99	402	405	414
48	196	197	201	100	406	410	418
49	200	201	205				
Viscosities, over 100 cs, multiply by . . .					4·06	4·10	4·18

A NOTE ON THE MODIFIED GRAY–KING ASSAY OF OIL SHALE*

By Geo. E. Mapstone †

The modified Gray–King assay of oil shale as used at Glen Davis provided for cooling the oil receiver with dry ice for the recovery of the lower-boiling naphtha, which was otherwise lost,[1] but no quantitative figures of this loss were available. Also, the low-temperature assay of coal by the Gray–King method[2] does not provide for cooling the tar receiver, while the high-temperature carbonization procedure requires cooling by means of an ice

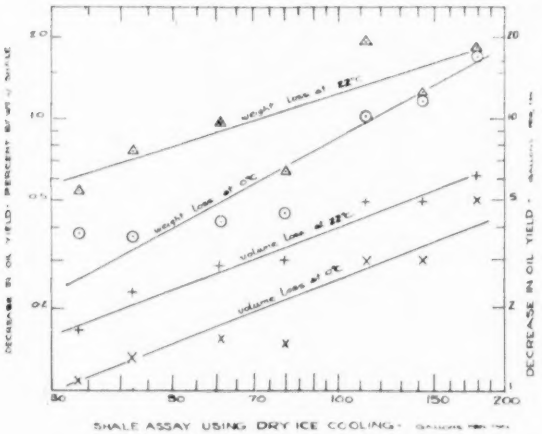


Fig 1

INFLUENCE OF COOLING BATH TEMPERATURE ON ASSAY LOSS

bath. The work reported here was therefore carried out to obtain some quantitative data on the effect of the cooling bath temperature.

A series of assays was carried out on various quality oil shales, using both the dry-ice and ice baths, and also a water bath at 22° C, as this was the mean summer tap-water temperature. The results of these tests are given in Table I.

The general trend of the results showed an increase of naphtha loss with yield, which was appreciably higher with the warmer receiver bath temperature, and the results themselves were, within the range of experimental error, a simple power function of the assay.

The relationships given tentatively in Fig 1 are suitable for predicting

* MS received 22 January 1952.

† C.S.I.R.O, Coal Research Section, Chatswood, N.S.W.

TABLE I

Influence of Cooling Bath Temperature on Shale Assay

Assay no.	Dry ice bath			Bath temp −0 + 1° C					Bath temp + 22° C				
				Results			Losses		Results			Losses	
	Gal/ton	% by wt	Sp. gr. of oil	Gal/ton	% by wt	Sp. gr. of oil	Gal/ton	% by wt	Gal/ton	% by wt	Sp. gr. of oil	Gal/ton	% by wt
(1)	33·7	13·27	0·8810	32·5, 32·7 } 32·6	12·85, 12·92 } 12·89	0·8870, 0·8845	1·1	0·38	32·1, 32·0 } 32·05	12·75, 12·70 } 12·73	0·8887, 0·8890	1·65	0·54
(2)	42·1	16·50	0·8782	40·7, 40·8 } 40·75	16·15, 16·10 } 16·13	0·8885, 0·8849	1·35	0·37	39·6, 40·0 } 39·8	15·65, 15·80 } 15·73	0·8843, 0·8853	2·30	0·77
(3)	*60·8, 60·9 } 60·85	23·78, 23·63 } 23·70	0·8762, 0·8692	59·4, 59·2 } 59·3	23·30, 23·25 } 23·28	0·8768, 0·8805	1·55	0·42	57·9, 58·1 } 58·0	22·70, 22·75 } 22·73	0·8780, 0·8769	2·85	0·97
(4)	*79·7, 79·5 } 79·6	31·15, 30·90 } 31·03	0·8752, 0·8715	77·9, 78·2 } 78·1	30·58, 30·58 } 30·58	0·8783, 0·8760	1·50	0·45	77·6, 77·6 } 77·6	30·35, 30·42 } 30·39	0·8764, 0·8763	2·0	0·64
(5)	112·3	43·85	0·8745	109·2, 109·4 } 109·3	42·73, 42·93 } 42·83	0·8766, 0·8784	3·0	1·02	107·3, 107·5 } 107·4	42·06, 41·85 } 41·93	0·8777, 0·8716	4·9	1·92
(6)	142·0, 142·2 } 142·1	54·75, 54·75 } 54·74	0·8637, 0·8622	139·2, 139·0 } 139·1	53·60, 53·50 } 53·55	0·8623, 0·8622	3·0	1·19	137·1, 137·1 } 137·1	53·33, 50·60 } 53·47	0·8712, 0·8749	4·95	1·27
(7)	183·6, 183·8 } 183·7	71·33, 71·40 } 71·37	0·8708, 0·8707	178·9, 178·4 } 178·7	69·70, 69·60 } 69·65	0·8735, 0·8745	5·0	1·72	177·3, 177·9 } 177·6	69·45, 69·66 } 69·55	0·8778, 0·8777	6·1	1·82

* Blended samples.

the loss of oil, either by weight or by volume, which will be experienced by using the ice or water bath. Within the same limits of accuracy, they may also be used to determine the correction that should be added to the observed yield at higher condenser temperature to give the yield with dry-ice cooling.

Acknowledgments

The author wishes to acknowledge with thanks the assistance of Mrs L. Nartsissov in carrying out the work, and the permission granted by the Management of National Oil Pty. Ltd. for the publication of the results.

References

[1] Mapstone, G. E. "Assaying Oil Shale," Second Oil Shale and Cannel Coal Conference, July 1950.
[2] "Methods of Analysis of Coal and Coke," H.M.S.O., London, 1940.

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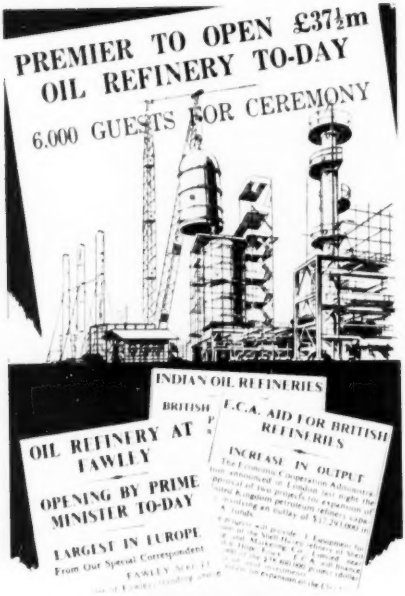

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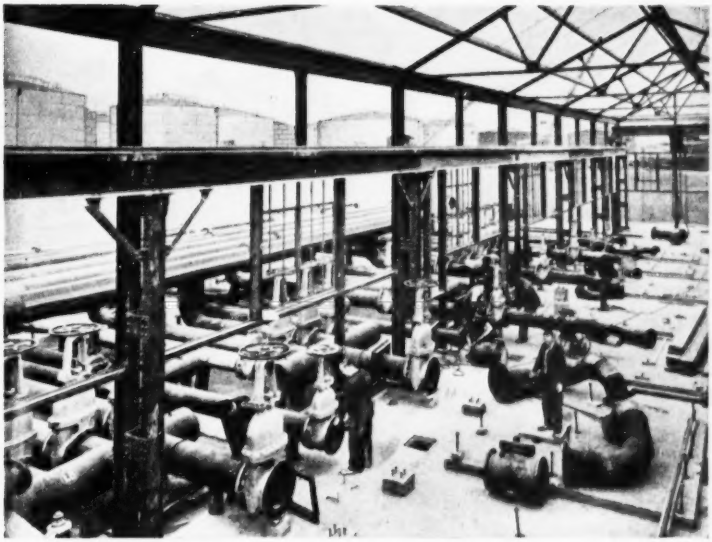

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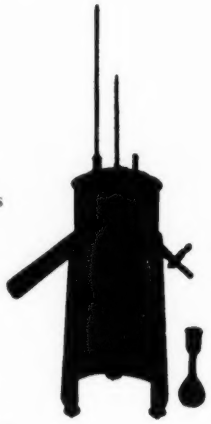

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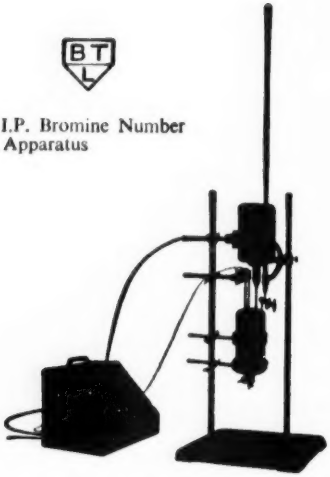

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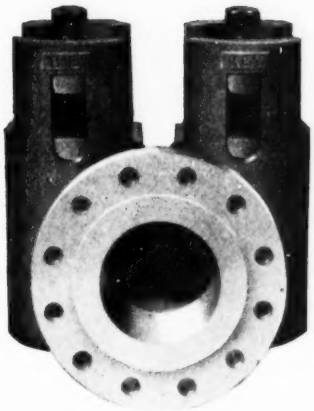

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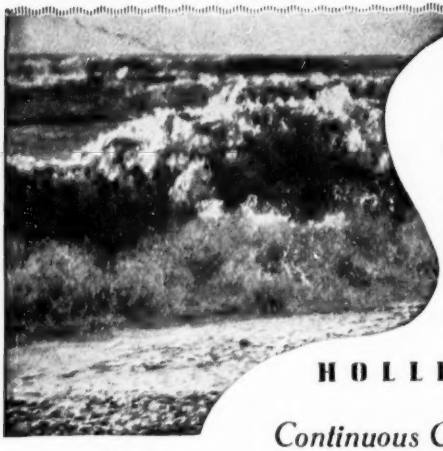

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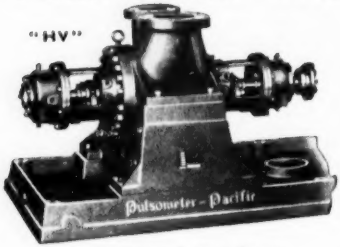

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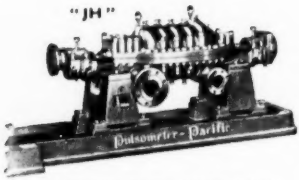

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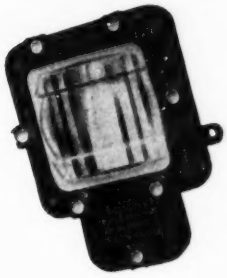

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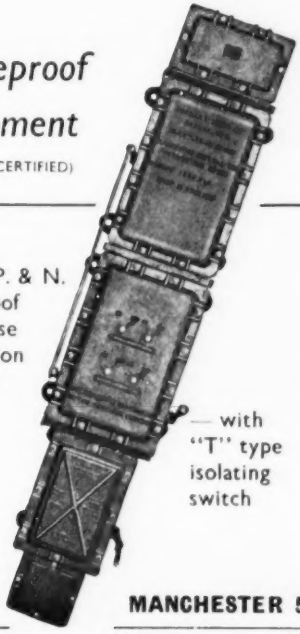

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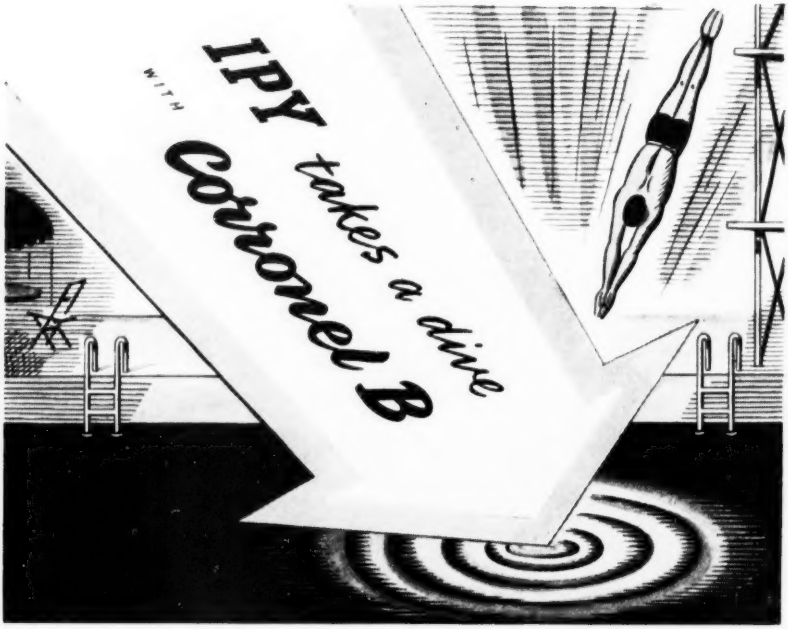

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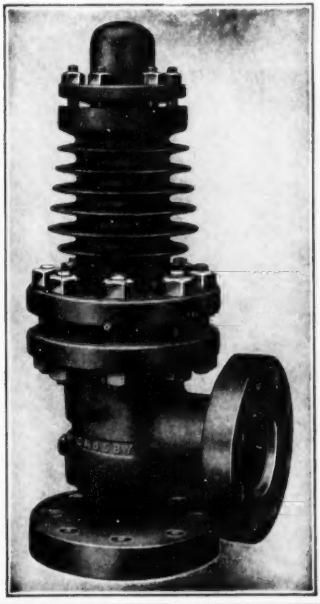

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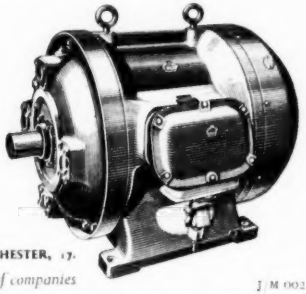

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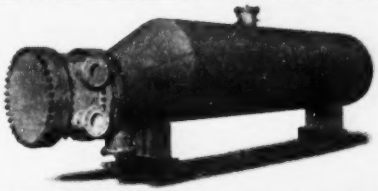

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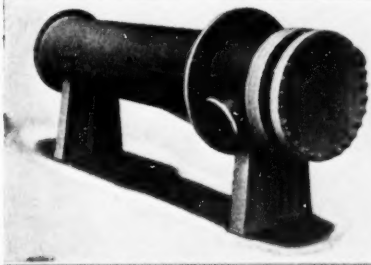

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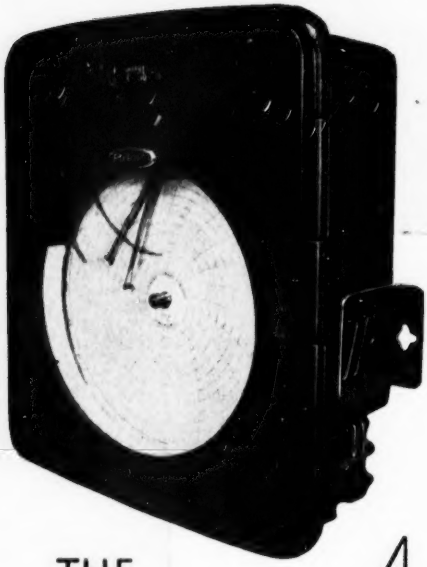

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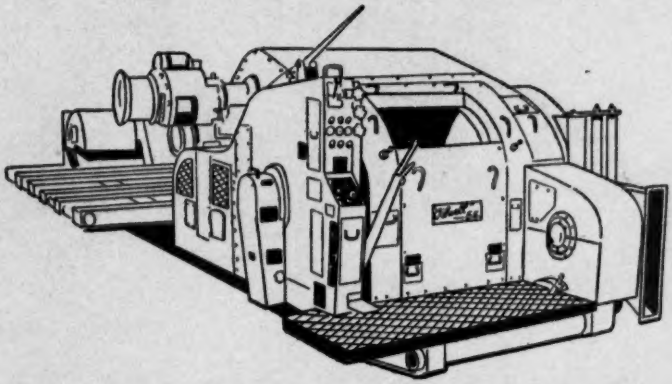

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